ATMOSPHERIC INFRARED SOUNDER ON AIRS

WITH EMPHASIS ON LEVEL 2 PRODUCTS

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Abstract— The Atmospheric InfraRed Sounder (AIRS) was launched aboard EOS Aqua in May of 2002. AIRS is a grating spectrometer with almost 2400 channels covering the 3.74 to 15.40 micron spectral region with a nominal spectral resolution (v/δv) of 1200, with some gaps. In addition, AIRS has 4 channels in the NIR/VIS region. The AIRS operates in conjunction with the microwave sounders Advanced Microwave Sounding Unit (AMSU-A) and Humidity Sounder of Brazil (HSB). The microwave sounders are mainly used for cloud clearing of IR radiances, or to remove the effect of cloud on the IR radiances.

AIRS has been very stable, radiometrically, as well as spectrally, meeting all stability requirements. All level 1 products (calibrated radiances) and level 2 products (retrieved geophysical parameters) have been released to the public. The primary level 2 products of the AIRS sounding suite include temperature, water vapor and ozone profiles, as well as cloud and surface parameters. AIRS science team members are also working on retrieving atmospheric aerosols, SO2, CO and CO2.

Use of the AIRS data, with its high spatial resolution and accuracy, can be expected to lead to significant advances in atmospheric research and climate studies, as the data sets are beginning to see extensive use in the research community. We will describe the AIRS data products and discuss the significant effort under way to improve the accuracy and scope of the retrievals. and the quality control that has been developed to make the data useful for assimilation and research at this early stage of the mission.

Keywords; infrared spectrometer, remote sensing, EOS Aqua

I. INTRODUCTION

The Atmospheric Infrared Sounder (AIRS) is one of six instruments launched onboard (one word?) the Aqua spacecraft on May 4, 2002, from Vandenberg Air Force Base in California. The AIRS sounding system is made up of three instruments: AIRS, the Advanced Microwave Sounding Unit (AMSU-A) and the Humidity Sounder of Brazil (HSB)[1].

The AIRS suite of instruments will observe the global water and energy cycles, climate variations and trends, and the climate system response to increased greenhouse gases by making highly accurate measurements of air temperature and humidity, clouds, and surface temperature.

The EOS Aqua platform is in a polar, sun-synchronous orbit with a nominal altitude of 705 km, an inclination of 98.2° and an orbital period of 98.8 minutes. The repeat cycle is 233 orbits (16 days) with a ground track repeatability of +/- 20 km. The platform will have equatorial crossing times of 1:30 AM (descending) and 1:30 PM (ascending).

AIRS is a continuously operating cross-track scanning infrared sounder. AIRS has almost 2400 channels in the 3.4 to 15 μm infrared region with some spectral gaps, and a nominal spectral resolution of about 1200. The instantaneous field of view of the AIRS channels is 1.1° x 0.6°, which corresponds to about 15 km at the nadir. AIRS has scan rate of 8/3 seconds.

AMSU-A is a 15-channel microwave temperature sounder. AMSU-A has 2 channels, 23.8 GHz and 31.4 GHz, which provide surface and moisture information (total precipitable water and cloud liquid water), 12 channels in the 50-58 GHz oxygen absorption band which provide the primary temperature sounding capabilities, and one channel at 89 GHz which provides surface and moisture information. Like AIRS, AMSU-A is a cross-track scanner, but with scan rate of 8 seconds. AMSU-A footprints (45 km at nadir) are approximately three times as large as those of AIRS. The result is three AIRS scans per AMSU-A scan and nine AIRS footprints per AMSU-A footprint.

Special attention is paid to ensure good collocation of AIRS footprints to footprints of the MW instruments. Normally, instruments scan perpendicular to the satellite track as the satellite travels. This introduces an angle between the cross–track and the line connecting the footprints, called the helix angle, which depends on scan rate. Since AMSU scans three times slower than AIRS (and HSB), the AMSU helix angle is significantly larger than

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[1] HSB scanner stopped in early Feb 2003 after 8 months of operation. Attempts to restart the scanner have not been successful yet.

that of AIRS. Even HSB and AIRS have slightly different helix angles due to slightly different scan timing. Although they have the same scan cycle of 2.67 seconds, their ground scan speed is slightly different. AMSU-A and HSB were rotated slightly on the platform to compensate for the difference in helix angles.
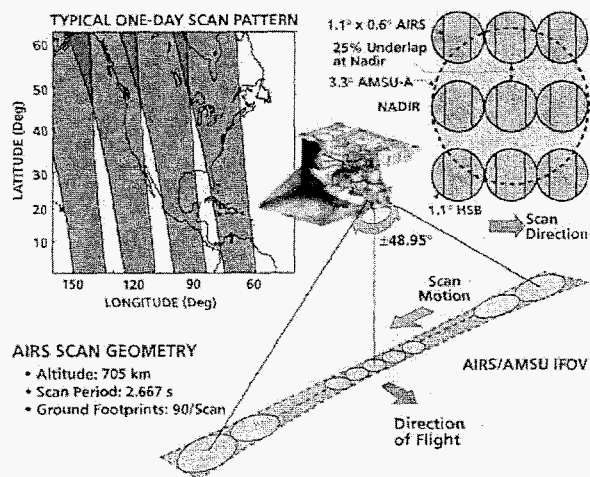

Figure 1: Scan Pattern of AIRS Sounding Suite

II. AIRS LEVEL 1 DATA PRODUCTS

The following is a plot of noise equivalent delta temperature (NeDT) at 250 K for the AIRS spectral channels. Many of the channels have NeDT of 0.1 to 0.2K, with the exception of the longer–wavelength IR channels. Many of the longwave channels are sensitive to stratospheric temperature where effects of clouds or the surface are negligible. AIRS performs retrievals at the AMSU footprint-scale, averaging those channels (not clear to me). Therefore, the relatively large values of NeDT have only a marginal effect.
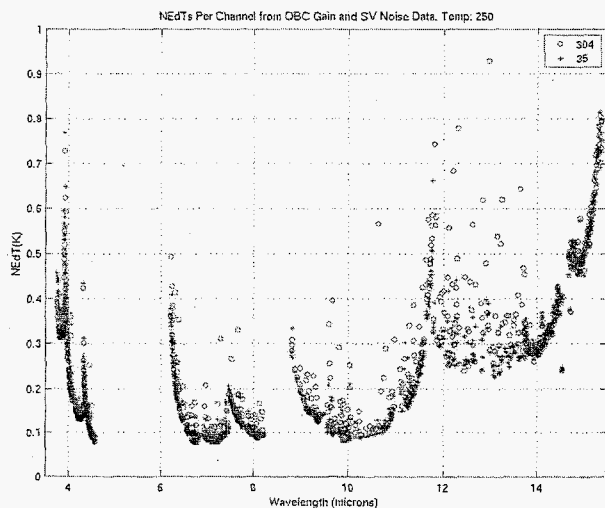

Figure 2: Instrument Noise Characteristics of AIRS

The following figure (courtesy of George Aumann) illustrates the radiometric stability of the AIRS 2616 cm-1 channel over the 16–month period starting in September 2002. The figure has the daily mean and bias of skin temperature estimated from the 2616 cm-1 channel with respect to the NCEP RTG (define!) SST. The mean bias is -0.64K and is stable at the rate of 5 mK per year. The data is collected from night (descending) orbits over clear ocean footprints with satellite zenith angle less than 35 degrees.
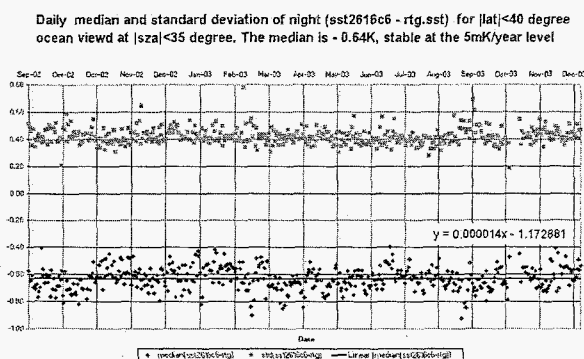

Figure 3: Radiometric Stability of AIRS

The following figure (courtesy of S. Gaiser) shows the spectral stability of AIRS. The AIRS spectral calibration software package estimates focal plane displacement from the shape of a selected set of absorption lines. The stability of this displacement is a direct measure of spectral stability. The AIRS was turned off when strong solar storm activity was observed at the end of October 2003. It took a couple of weeks to stabilize the spectral properties of AIRS. This shows up on the figure as a glitch starting at the end of October 2003, and lasting about three weeks. With the exception of this time period, the spectral properties are extremely stable. The figure seems to indicate a very small negative slope. The effect of this trend on spectral frequencies and radiances is estimated to be very small. We will need to observe the trend for a longer period of time before any analysis of the trend itself can be attempted.
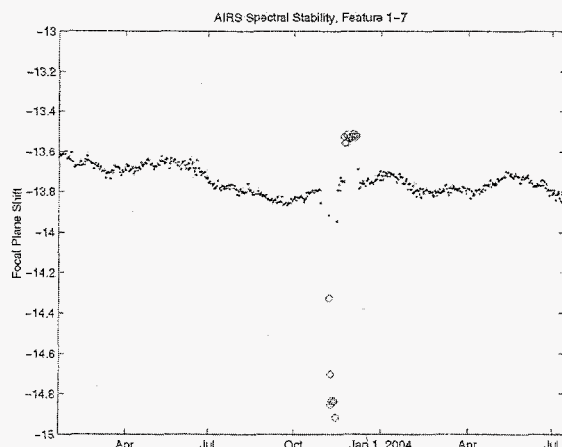
Figure 4: Spectral Stability of AIRS

III. AIRS LEVEL 2 DATA PRODUCTS

The AIRS retrieval algorithm is described in Susskind et al [2]. This is a unified algorithm with many components from other AIRS science team members. First, MW only retrievals are performed and cloud clearing is attempted using the MW only retrieval as a first guess, then the regression retrieval is attempted to further refine the retrievals, and then the final physical retrieval is attempted.

It is estimated that only a few percent of AIRS observations are clear enough that the net effect of cloud on AIRS radiances is smaller than 1K. Through cloud clearing, that is, removing the effect of cloud on the radiances before attempting a geophysical retrieval, we can raise the yield to somewhere between 40 and 60% of AIRS observations at AMSU resolution, depending on the degree of tolerance for outliers. The cloud clearing is an extrapolation of cloudy radiances to clear radiances and exaggerates noise, especially when the contrast between AIRS footprints is small or when the cloud is optically thick. Also, the cloud clearing assumes uniformity (uniformity of what, temperature and moisture fields?) between AIRS footprints, which is not always met. When the uniformity assumption fails and is not detected, this algorithm produces outliers. Therefore, we work very hard to detect and understand outliers.

The standard AIRS level 2 parameters include temperature, water vapor, and ozone profiles, surface parameters such as surface skin temperature, and cloud parameters including effective cloud fraction and cloud top pressure. AIRS produces a combined IR/MW product almost 90% of all AMSU footprints in version 4.0. This does not imply that all AIRS products written to the output files are valid. There are many flags for version 4 that indicate the quality of particular products. It is important that data users are familiar with the quality flags. For example, the flag Qual_H2O should be examined when water vapor products are used. Also, surface skin temperature will have high quality only when the flag Qual_Surface indicates so.

All Level 2 products with the exception of cloud fraction are produced at the AMSU-A footprint resolution (45 km at nadir). The spatial resolution of AIRS cloud fraction is at the AIRS spatial resolution, or 15 km at nadir.

The AIRS Level 2 files range in size from 4.7 to 20 MB, with each file containing approximately 6 minutes of satellite coverage data, for a total of 240 files per day, per instrument, per processing level. The Level 2 files are broken down further into standard and support files; the size of a single 6 minute Level 2 standard file is 4.7 MB and for a single Level 2 support file is 18 MB. The total daily volume for Level 2 standard products is about 1.1 GB per day; for support products, the total is about 4.3 GB per day.

IV. VALIDATION OF AIRS PRODUCTS

The version 3 AIRS level 2 data products became public in early 2003, available from the Goddard DAAC. This was the first release of level 2 data products. The validation of AIRS data products is proceeding in stages. The AIRS level 1b radiances, as well as the temperature profiles, are provisionally validated over non-polar ocean surfaces for version 3. The term "provisionally validated" means that the product in question can be used for scientific analysis with caution. The version 4 products are scheduled for public release in early 2005. More products will be validated as well as some products over non-frozen land surfaces.

The AIRS project set the goal of achieving "global sounding from satellite with the accuracy of radiosondes". With the upcoming version 4 release we will have achieved this goal over certain unfrozen land surfaces, as well as over unfrozen ocean. The next figure shows the bias and the RMS difference of AIRS temperature profiles with respect to ECMWF analyses over the unfrozen ocean in a prerelease version of version 4 data products. We are achieving the goal of 1K RMS in 1 km layers in the troposphere.
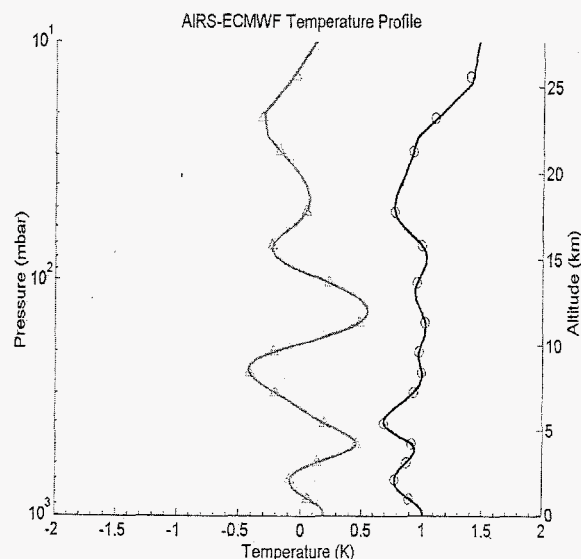
Figure 5. Statistics w.r.t. ECMWF Analysis

Each release of AIRS data is accompanied by a validation report, a user guide, and other documents. The validation report for version 4 will include validation of water vapor, cloud products, ozone as well as temperature.

V. AIRS LEVEL 3 PRODUCTS

Level 3 products will be released with the version 4 AIRS data release. Many of the level 2 data products are average at a spatial resolution of 1°x1° for each day. Ascending orbits (day side) will be averaged separately from the descending (night side) orbits. Since level 3 products include counts as well as means, multi-day level 3 products for any number of days can be generated from the daily level 3 products. The temporal resolution of the products generated at Goddard DAAC is daily, 8-day (half of the 16 day Aqua orbit repeat cycle) and monthly.
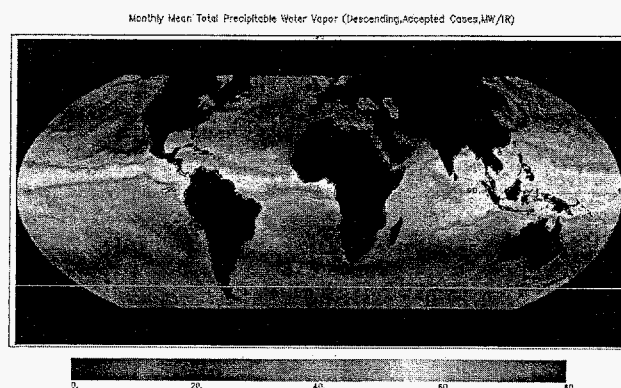
Monthly Mean Total Precipitable Water Vapor (Descending,Accepted Cases,MW/IR)

Figure 6. Total Precipitable Water Vapor for May 2003

Monthly Mean Total Precipitable Water Vapor (Descending,RType < 100,MW Only)
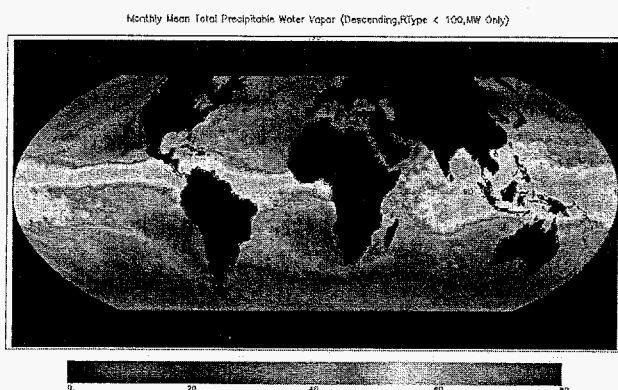

Figure 7. MW Only Total Precipitable Water Vapor for May 2003

The above two figures are maps of monthly mean total precipitable water vapor from the descending orbits for May 2003. The first is the AIRS/AMSU combined product, while the second is MW only product. Notice that MW only products are used as a guess to the combined product. Since cloud clearing is known to fail for precipitating or very cloudy scenes, the MW product tends to be wetter than the combined product. This is why we have MW only products as well as combined products in the level 3. Although combined products are of higher quality, its sampling characteristics can become troublesome issues.

VI. OTHER SOUNDER DEVELOPMENT AT JPL

JPL is developing two more sounders for possible future missions. Both are under Instrument Incubator Program (IIP) and applicable to MEO as well as GEO missions. T. Pagano is working with Ball Aerospace on Spaceborne InfraRed Atmospheric Sounder (SIRAS). This is a grating spectrometer like AIRS. B. Lambrigtsen is working on the Geostationary Synthetic Thinned Aperture Radiometer (GeoSTAR). This will have AMSU-like channels working from geostationary obit.

ACKNOWLEDGMENT AND CLOSING REMARKS

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